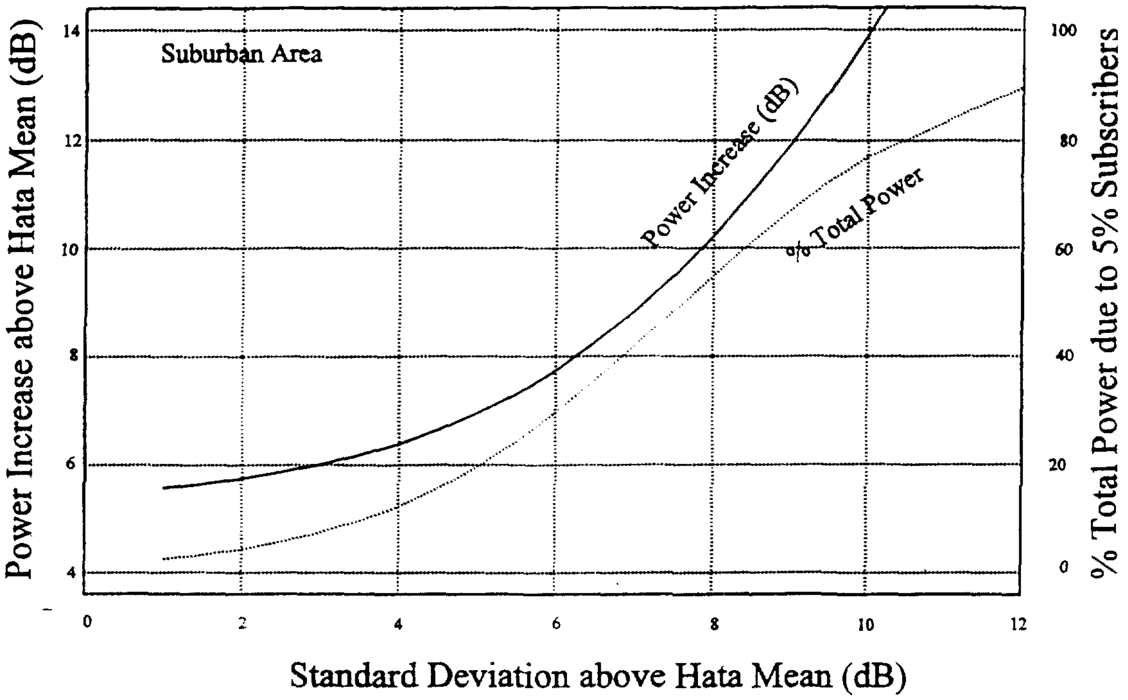

Figure F-4.3 Power Increase above Hata Mean vs. Standard Deviation for Suburban Environments

F-4.4.2 PCS Low Base Antenna to MW Site

For low PCS base site antennas (3 m to 9 m), use Equation F-4-7, with statistical corrections as necessary, replacing the portable or mobile height in Equation F-4-7 with the PCS base antenna height.

F-4.4.3 PCS High Base Antenna to MW Site

For high PCS base with heights from 9 m to 60 m with the MW antenna less than 180 m, follow the procedure of Section F-4.4.1, except use Equation F-4-7 with a new base height gain factor as given below. This factor approximates the theoretical plane earth height gain formula.

$$\alpha(h_{Base}) = 3.2 \left[\log(11.75\ h_{Base})\right]^2 - 4.97 \qquad \text{(F-4-10)}$$

For PCS base heights greater than 60 m and MW antennas greater than 180 m, the free space loss Equation F-4.11 should be used out to the smooth earth transition distance. The case of PCS base heights greater than 60 m and MW antenna heights less than 180 m is still under investigation. In the interim, use free space loss Equation F-4-11 for this situation. For PCS base less than 60 m and MW antennas greater than 180 m, use Equations F-4-7 and F-4.10.

$$L_{fs} = 32.4 + 20\ \log(d) + 20\ \log(f) \qquad \text{(F-4-11)}$$

Summary PCS Base to MW Path Loss

PCS Base Height (m)	**MW Height (m)**	**Method**
≤ 9	all	Section 4.4.1
> 9 and ≤ 60	all	Section 4.4.1 & Equation F-4-10
> 60	≤ 180	Free Space (Interim Recommendation)
> 60	> 180	Free Space Equation F-4-11

F-4.4.4Hata to Transhorizon Transition

Because the local ground clutter lifts the propagation loss above free space loss and has a loss slope from 30 to 40 dB/decade distance, the transition from Hata propagation to transhorizon propagation will occur farther out than indicated by Equation F-4-1. A series of graphs for various antenna heights illustrates this point.

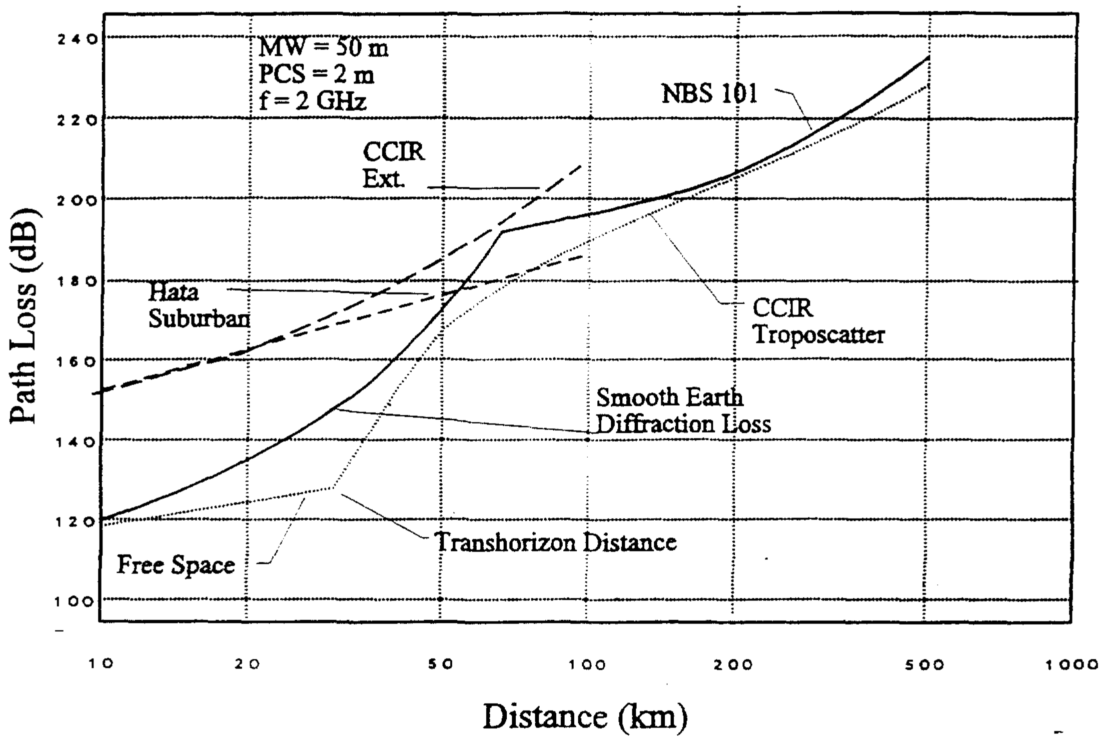

Figure F-4.4 Propagation Models for Low Microwave and PCS Mobile Antennas

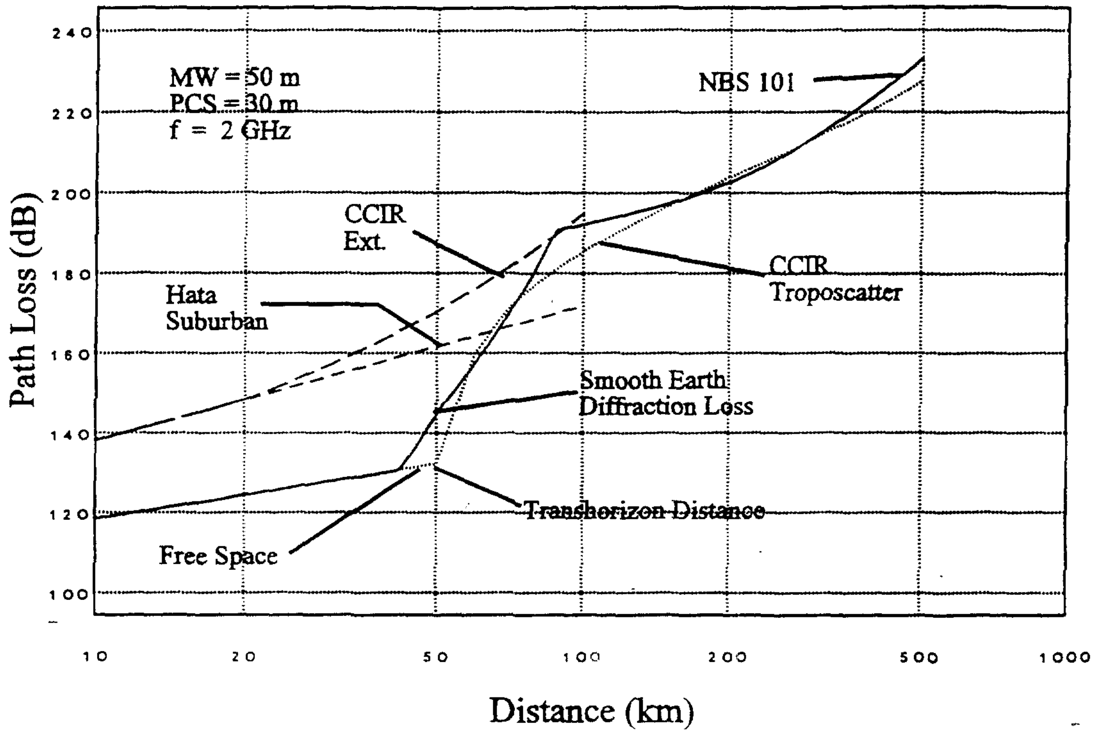

Figure F-4.5 Propagation Models for Low Microwave and PCS Base Antennas

The solid curve is based on *NBS Tech Note 101*[22] and covers from free space to smooth earth diffraction to forward scatter loss. The smooth earth diffraction section follows very closely the predictions of *CCIR Rep. 715-3*.[23] The forward scatter loss is from *CCIR Rep. 238-6*.[24] It is seen that the *NBS 101* curve merges into the CCIR forward scatter loss (troposcatter) curve. To further illustrate the interaction of Hata with this transition region, four more curves follow at various antenna heights.

---

[22] G. Hufford, A. Longely, and W. Kissick, "A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode", *NTIA Report 82-100* (PB 82-217977), April 1982.

[23] CCIR, Propagation in Non-ionized Media, Volume V Annex, *Report 715-3*, "Propagation by Diffraction", Dusseldorf, 1990.

[24] CCIR, *Propagation in Non-ionized Media, Volume V Annex, Report 238-6*, "Propagation Data and Prediction Methods Required for Terrestrial Tran-Horizon Systems", Dusseldorf, 1990.

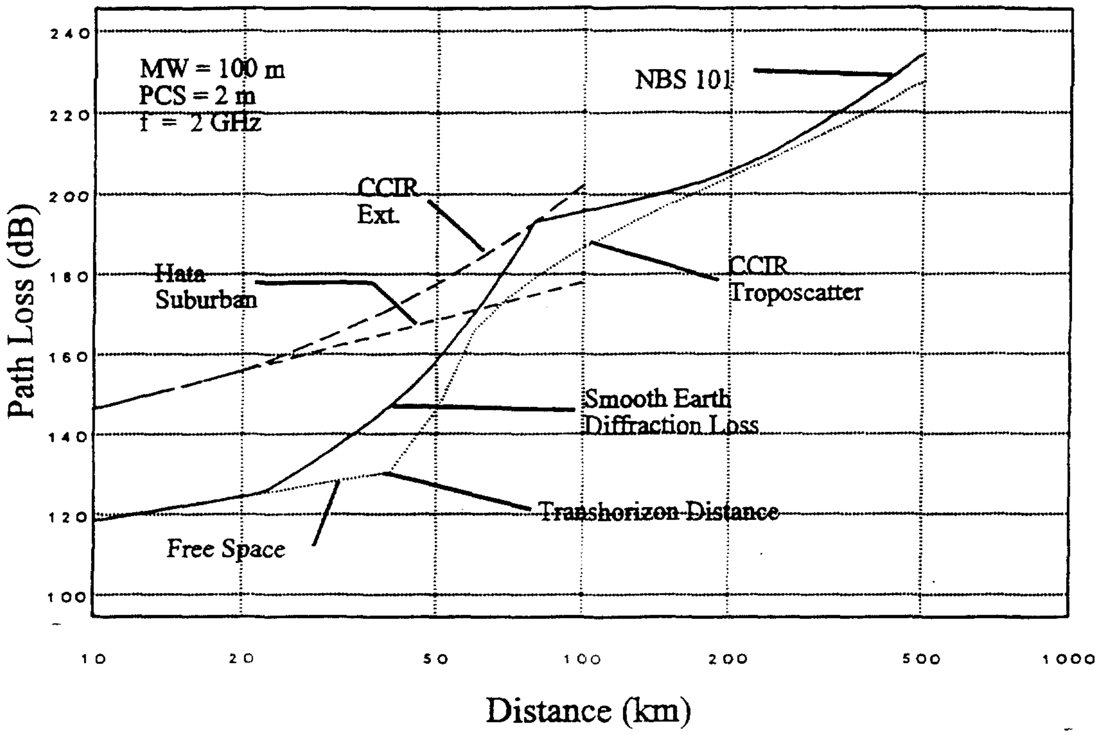

Figure F-4.6 Propagation Models for Medium Microwave and PCS Mobile Antenna

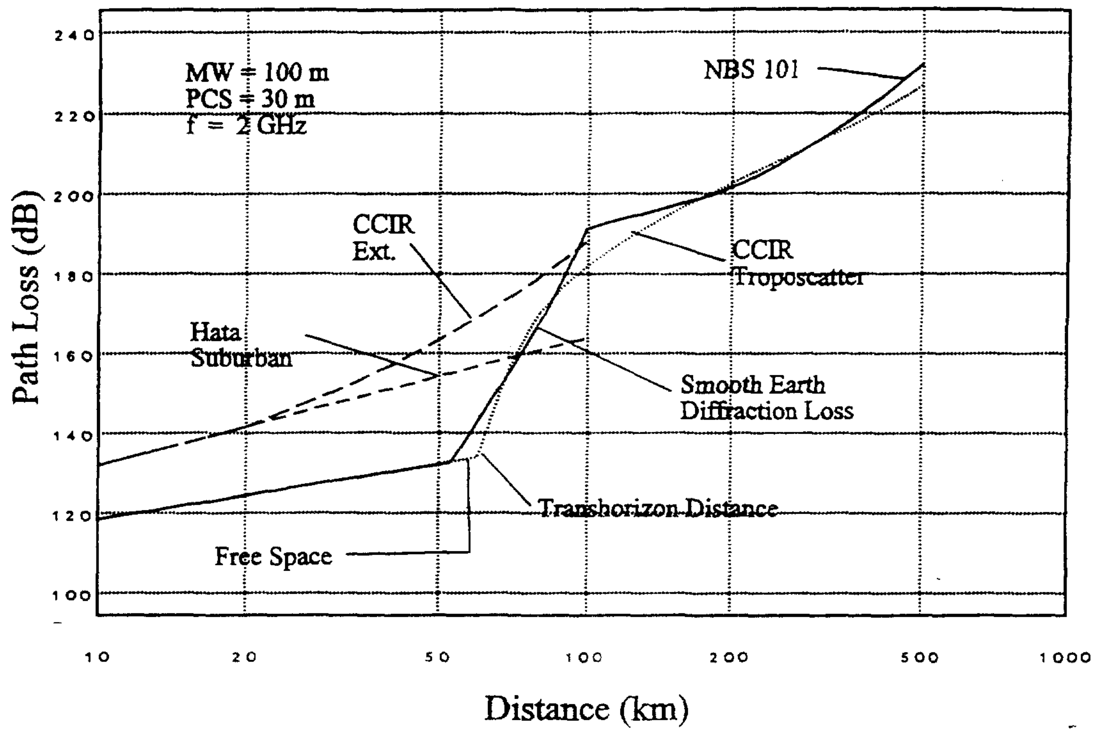

Figure F-4.7 Propagation Models for Medium Microwave and PCS Base Antennas

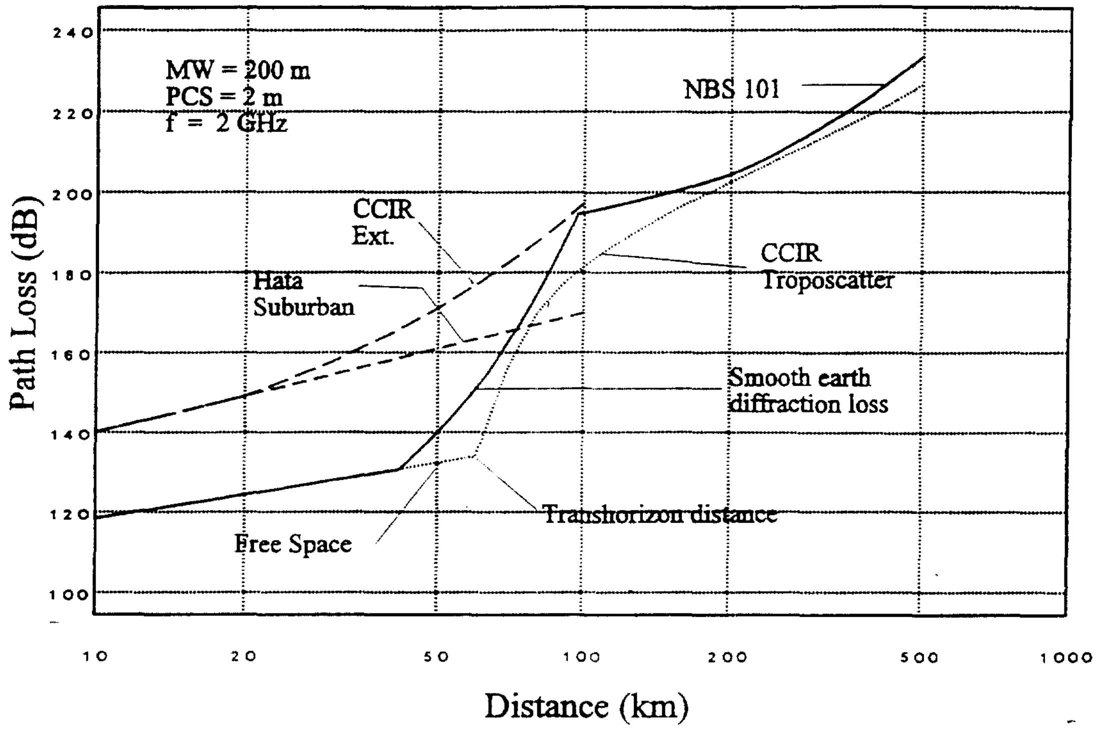

Figure F-4.8 Propagation Models for High Microwave and PCS Mobile Antennas

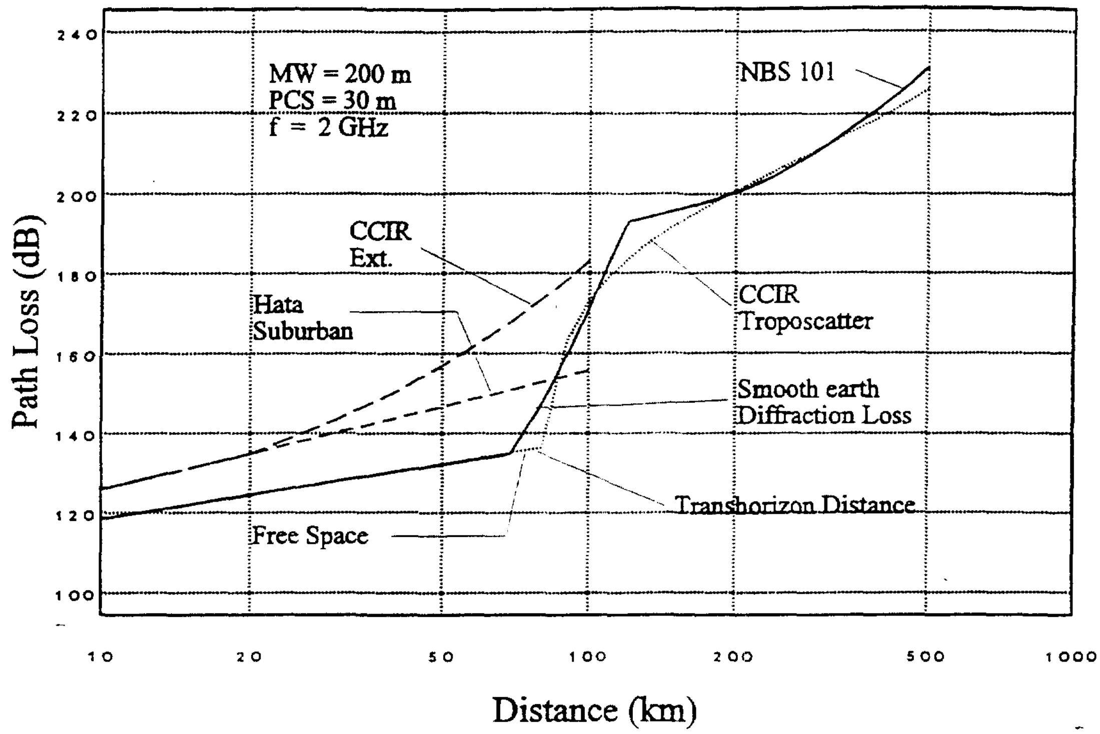

Figure F-4.9 Propagation Models for High Microwave and PCS Base Antennas

The previous six graphs cover microwave antenna heights from 50 to 200 meters and PCS antenna heights from 2 to 30 meters. Note that the Hata suburban curve (without the CCIR extension), the diffraction curve, and the troposcatter curve all tend to come together at a point on each graph. The distance where they come together is a function of the antenna heights involved. The following graph is a plot of the smooth earth transition distance (Equation F-4-1) for the antenna situations illustrated in the graphs to the three curve merging point distance on each graph.

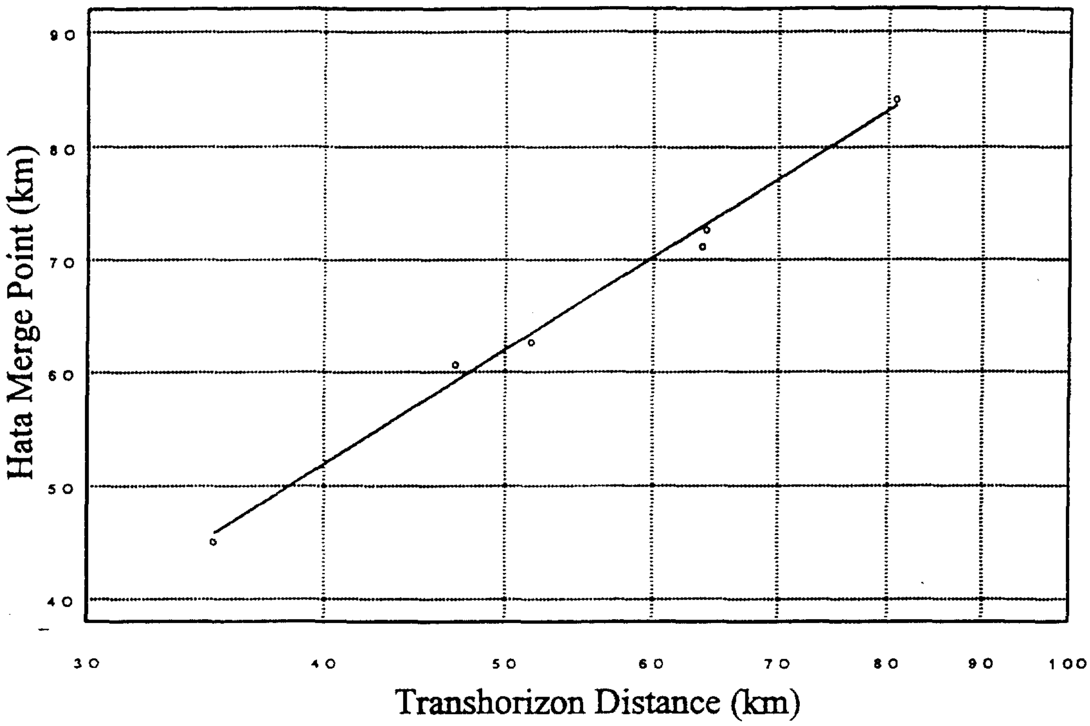

Figure F-4.10 Transition from Hata Suburban Distance as a Function of Smooth Earth Transition Distance

The Hata merge point appears to follow the log of the theoretical smooth earth transition distance for each antenna situation. So the Hata merge point can be estimated by

$$d_{hata} = -115 + 105 \log_{10}(d_h) \qquad \text{(F-4-12)}$$

where:

d_{hata} = the Hata merge distance (km)

d_h = the transition distance given in Equation F-4-1

F-4.4.5 Irregular Earth Transhorizon

The irregular earth transhorizon is modeled[25] by adding an irregular terrain factor in meters. The magnitude of this factor causes the transhorizon distance to shift but has less effect on the merge point with

[25] G. Hufford, A. Longely, and W. Kissick, "A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode", *NTIA Report 82-100* (PB 82-217977), April 1982.

Hata so that Equation F-4-2 can still be used at least with terrain irregularity up to 50 meters. This is illustrated in the graph on the next page.

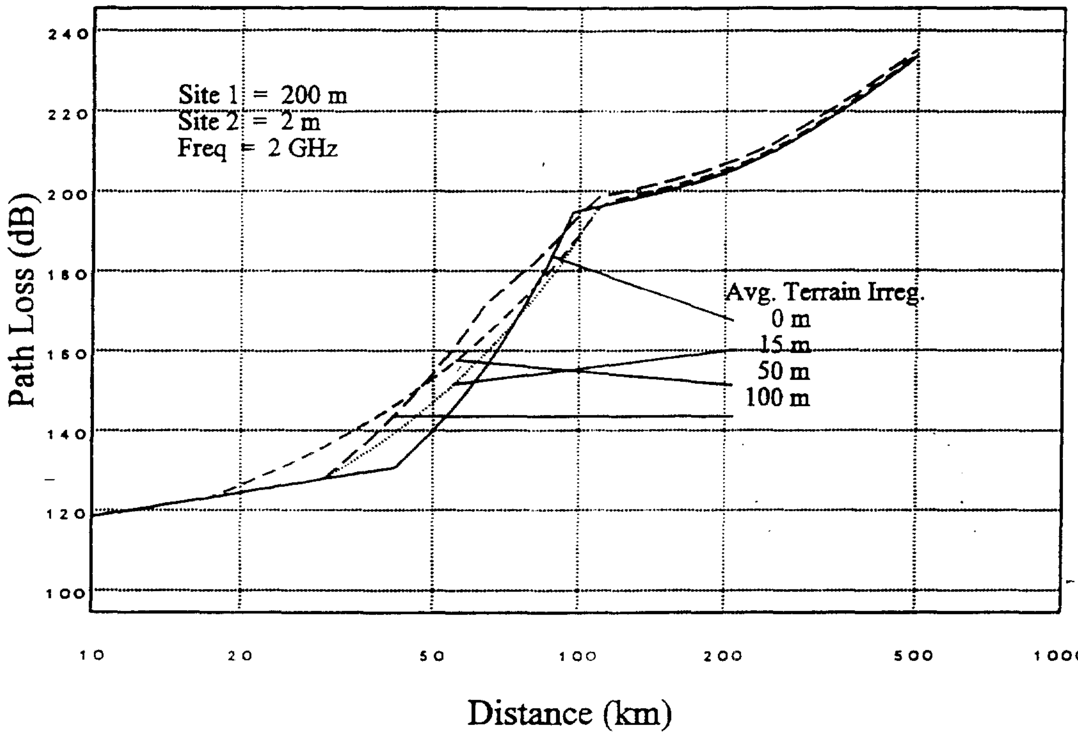

Figure F-4.11 — Propagation Model Transition Region as a Function of Terrain Irregularity

F-4.4.6 Path Loss Summary

The propagation models given in Equations F-4-1 through F-4-12 are very general but useful for a quick look at potential coordination problems. In particular, it is recommended that for first pass PCS to microwave coordination, the Hata suburban models, Equations F-4-7 to F-4-11 with the appropriate statistical corrections, be used up to the distance given in Equation F-4.12 and that the *CCIR Rep. 238-6* troposcatter model, Equations F-4-2 to F-4-6, be used for distances beyond. When problems do occur using the simple models or there are obvious terrain or building situations that invalidate the simple model's flat terrain assumptions there are two alternatives:

1) Coordination can be based on actual path loss measurements to the victim site in question,

or

2) Coordination can be based on more sophisticated computer models with urban building and terrain overlays to account for excess losses due to tall buildings or hilly terrain between PCS license areas and the victim site. (See reference <24>)

United States Geologic Survey (USGS) Digital Elevation Models (DEM) are available for all the continental United States with data points every 3 arc seconds (roughly 100 meters latitude). The USGS is also digitizing their 7.5 minutes maps to a 30 meter grid. Some of these databases are also available. Terrain databases have been incorporated into commercial propagation coverage programs. Modifications to these programs using the propagation models recommended in this annex would be a useful tool for more accurate coordination studies.

F-4.5 PCS antenna height gain and building penetration loss.

Various studies have demonstrated a height gain function of X dB per floor (3 meters) to N floors, then 6 dB/octave[26] height change beyond that, with maximum gain set by free-space propagation assumptions.

X and N are functions of surrounding building heights, which in turn are typically functions of city model. See Table F-4.5. Building penetration loss tends also to be a function of city size.

F-4.5.1 Assumptions:

1. It is assumed that the average surrounding building clutter for a core urban area (*e.g.*, Chicago "Loop", Manhattan, *etc.*) is 16 stories height. Further, the similar clutter height of "dense suburban" (or "outer urban") is 11 stories and residential suburban is 6 stories (apartments, trees, *etc.*).

2. It is further assumed that the propagation phenomena above the clutter height is essentially "flat earth" and that no "nulls" occur between the transition point and that height where the net propagation loss is essentially "free space" (building exterior).

3. Therefore, it is assumed that the environmentally determined propagation differences disappear at the clutter heights above; that is, it is assumed that the external[27] propagation loss for the various environments is equal at the specified clutter heights. [In other words, net propagation loss for "residential suburban" at the 6th floor is equal to that at the 16th and 11th floors of "core urban" and "dense suburban" area, respectively.]

4. Beyond the "clutter height" floor, propagation loss decreases at 6 dB/octave until external net propagation loss is reduced to that of "free space".

5. Then, net assumed building penetration loss is added to the external loss.

Core urban building height gain is assumed to be 2.7 dB/floor to the 16th floor, then 6 dB/octave

[26] 6 dB per doubling of height, *e.g.* from 16th floor to 32nd floor.

[27] Not including loss into the building.

beyond that, in agreement with a number of industry studies.[28] Path loss to the exterior street is assumed to be per Section F-4.4 and building penetration loss is set at 18 dB.

Dense suburban building height gain is assumed to be 2.9 dB/floor to the 11th floor, then 6 dB/octave beyond that. Path loss to the exterior street is assumed to be per Section F-4.4 and building penetration loss is set at 15 dB.

Residential suburban building height gain is assumed to be 4.2 dB/floor to the 6th floor, then 6 dB/octave beyond that. Path loss to the exterior street is assumed to be per Section F-4.4 and building penetration loss is set at 13 dB.

Residential building height gain is assumed to be 0 dB. Path loss to the exterior street is assumed to be per Section F-4.4 and building penetration loss is set at 10 dB.

The following table summarizes this information:

City Model	N	Building Loss* (dB)	Loss sigma (dB)	X Loss Decrease (dB/floor) ***
Core Urban	16	18	7.5	2.7
Dense Suburban	11	15	8.5	2.9
Residential Suburban **	6	13	9.5	4.2
Residential	1	10	10	0

* Mean

** Suburban situations might typically involve a very tall modern office building in the center of a relatively open/residential/low building environment.

*** Decrease loss 6 dB/octave above "N" for the appropriate city model mode.

Table F-4.5 — Building Height Gain and Penetration Loss

[28] S. Kozono and K. Watanabe, "Influence of Environmental Buildings on UHF Land Mobile Radio Propagation", *IEEE Trans. Comm., COM-25*, pp. 1113-1143, October 1977.

E. H. Walker, "Penetration of Radio Signals into Buildings in the Cellular Radio Environment", *BSTJ*, Vol. 62, No. 9, pp.; 2719-2734, November 1983.

J. M. Durante, "Building Penetration Loss at 900 MHz", *IEEE Vehicular Technology Conference, VTC-73*, pp. 1-7, 1973.

A. M. D. Turkmani, J. D. Parsons, and D. G. Lewis, "Measurements of Building Penetration on Radio Signals at 441, 900, and 1400 MHz", *J. IRE*, Vol. 55, No. 6, pp. 5169-5174, June 1988.

W. J. Tanis and G. J. Pilato, "Building Penetration Characteristics of 880 MHz and 1922 MHz Radio Waves", *IEEE Vehicular Technology Conference, VTC-93*, pp. 206-209.

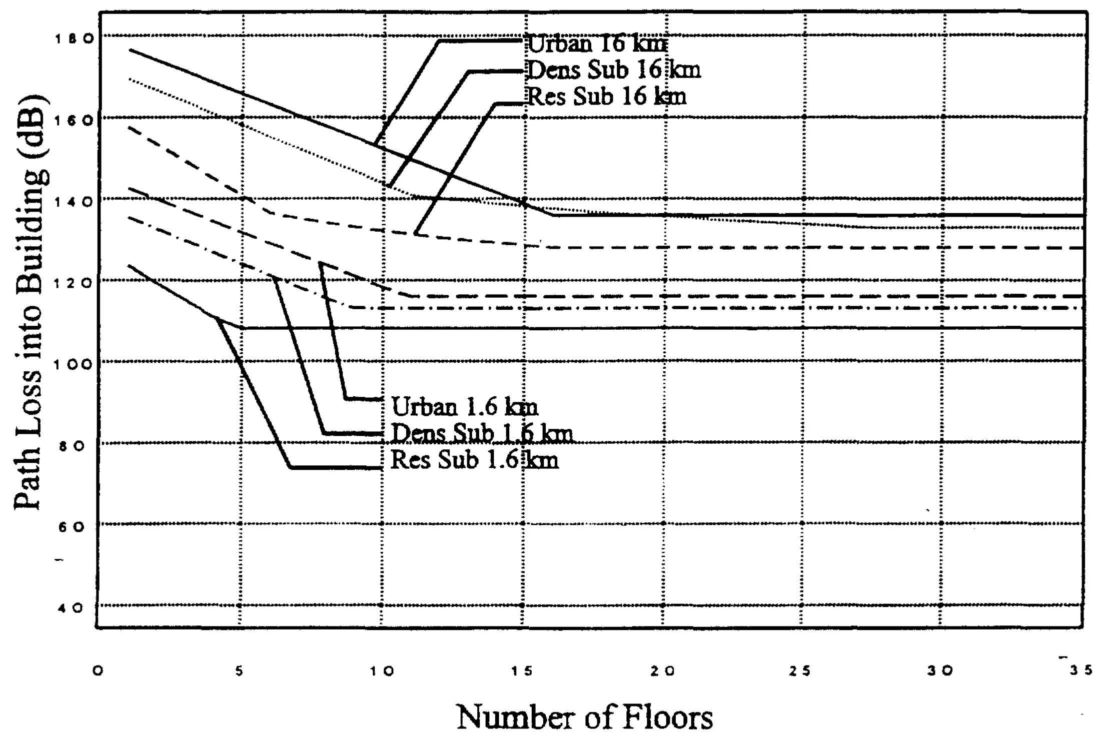

Figure F-4.12 — Path Loss into Buildings vs. Number of Floors

Figure F-4.12 shows examples of this model for distances of 1.6 and 16 kilometers, from the microwave antenna to the building street.

There are two PCS applications to be considered here, specifically outdoor and indoor. For outdoor applications (*e.g.* base station antenna locations), the height gain algorithm is applied directly, with a free-space limit test. For indoor applications, the height gain algorithm is applied first, with a free-space test next, then in-building losses are added.

> *Example: Street level propagation loss from PCS to the target microwave dish is calculated at 170 dB; a height gain factor of 40 dB is calculated, reducing tentative calculated propagation loss to 130 dB; but free-space loss is calculated to be 142 dB; then set external loss to 142 dB and add building penetration loss e.g. 15 dB; thus, net propagation loss is 157 dB (or alternately, effective height gain + building loss is 40-(142-130)+15=43 dB).*

F-4.6 Antenna pattern discriminations.

F-4.6.1 Microwave Antennas.

Both horizontal (azimuth) and vertical (elevation) antenna discriminations shall generally be included in interference calculations. For most cases of relatively large coordination distances, vertical discrimination effects will be minimal and can generally be disregarded. For "close in" situations, microwave antenna vertical discrimination effects can be significant. For interference calculations, for PCS transmitters located within the clutter, full microwave antenna pattern discrimination may not be realizable (see Reference 20).

F-4.6.2. PCS Antennas

Most PCS systems will tend to use omni-directional antennas for the base stations. However, some systems may employ directional antennas for purposes of either affecting the PCS coverage profiles or to purposely attempt to minimize interference effects to either other PCS cells or to area microwave facilities. In this case, significant clutter and resulting reflections can reduce the directional effectiveness of the antenna unless it is well elevated or otherwise removed from the clutter. The following criteria shall apply:

1) In a cluttered environment, a minimum antenna gain of -3 dB (-6 dB) is allowed where the (modified Hata) PCS-to-microwave path loss (not including antenna gains) is in excess of 10 dB (5-10 dB) of free-space path loss.

2) In a relatively uncluttered environment (modified Hata path loss calculation approaches to within 5 dB of free-space), or when an alternative terrain based propagation model is used, with antenna assumed above the clutter, the antenna manufacture's rated antenna isolation may be used.

Greater than 10 dB of free space loss:	-3 dB minimum
Within 5-10 dB of free space loss:	-6 dB minimum
Within 0-5 dB of free space loss:	Manufacturer's antenna specification

Example: A PCS system uses 12 dB gain (as measured quasi-free space on a range) directional (corner reflector) antennas with 20 dB rated front-to-back isolation ratios, to improve on-street directional coverage, powered by +20 dBm base station transmitters. The system has all antennas facing 180 degrees away from the at issue microwave receiver dish. Considering the antenna height gain factors (Section F.4.5) and distances involved, it is determined that one-third of the antennas demonstrate significantly greater propagation loss to the microwave than free space (e.g. >30 dB), one-third are within 5-10 dB and another third are within 0-5 dB of free space loss, when the antennas are considered as gain-less dipoles. Given this, the first third are allowed -3 dB antenna gain in the reverse direction (i.e., EIRP = +17 dBm), the second third are allowed -6 dB antenna gain (EIRP = +14 dBm) and the final third are allowed -8 dB antenna gain (manufacturer's rating, +12 dB - 20 dB) (EIRP = +12 dB).

[Note: Effective forward antenna gains will also be reduced in cluttered environments and, more generally, the entire effective antenna pattern will

be modified.]

F-4.7 Polarization Isolation

Most PCS systems will utilize fundamentally vertical radiation polarization while microwave systems will use either vertical or horizontal polarizations. It is recommended that no cross-polarization isolation between PCS and horizontal microwave systems be assumed, as the PCS is normally in a multi-path environment that results in substantial de-polarization effects. Exception should be applied whenever the combination of physical factors is such as to cause a near free-space propagation condition to exist ("near free-space" is defined as loss such that the increment to free-space is less than or equal to the potential polarization isolation). Under these conditions, free-space loss plus polarization isolation should be applied instead.

Example: A (typical) vertically polarized PCS system under study has a base station antenna that is at a significant height such that the calculated propagation loss to the microwave dish is at a free space value of 140 dB. However, the microwave is noted to be horizontally polarized with a cross polarization isolation of 20 dB. The net loss is therefore set at 140+20=160 dB. Another somewhat lower base station antenna in the system has a calculated propagation loss of 150 dB. Since this is within the range of free space to (free space + polarization isolation) i.e. 140-160 dB, its net loss is also set at 160 dB. [In essence, the minimum loss limit of "free space" is replaced by "free space plus polarization isolation".]

F-5 Active Avoidance Systems

As an alternative to the geographic separation methodologies described in Sections F-3 and F-4 of this annex, active avoidance systems that can adequately demonstrate they will meet the point-to-point microwave receiver interference criteria prescribed in Annexes A and B may be used.[29] While there are a variety of approaches that may be used by active avoidance systems, all employ some technique allowing them to determine if there is sufficient loss (isolation)[30] in the signal path between PCS transmitters (base stations, mobiles, and portables) and point-to-point microwave receivers, to prevent interference to the receivers. Some systems also determine if there is sufficient loss in the signal path to allow PCS receivers to be operated without significant interference in the vicinity of point-to-point microwave transmitters.

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29 The geographic exclusion method of interference avoidance involves making assumptions, such as with a propagation model, that generally involve levels of conservatism resulting in larger than necessary exclusion zones. This decreases the capacity of the system to support PCS units; if one could really "know" what the true propagation loss is for a given situation, additional spectrum capacity could be "mined" thereby allowing the system to support a greater number of PCS devices.

30 Isolation is defined as the total loss between the antenna ports of a transmitter and a receiver, not accounting for peak antenna gains on either end, but accounting for antenna discrimination. (Reference 20) When the antenna discrimination of both antennas is 0 dB, isolation corresponds to path loss. Isolation is given by:

Calculated Isolation = Path Loss + Total Antenna Discrimination

or

Measured Isolation = EIRP of Transmitter + Receiver Antenna Gain - Received Signal Power

F-5.1 Adequate Isolation

The methodology used for active avoidance must ensure that the PCS transmitters are not activated unless adequate isolation is present at the time and place of transmission. In order to achieve this, for example, some detection-based systems periodically attempt to receive signals from point-to-point transmitters, or special beacon transmitters, which share the same antenna as the receivers being protected. Depending on whether or not this signal is received, a "go/no-go" PCS transmit decision is made. The combination of detection system sensitivity and (potentially) detected transmitter signal power must be sufficient to ensure adequate RF isolation between the PCS transmitters and victim receivers.

For the active avoidance system to be used as an alternative to model-based approaches to determine whether sharing is possible, the isolation measured by the system at multiple locations within the coverage area of a PCS base station or a cluster of PCS base stations must meet or exceed the isolation computed at the same locations with the modified Hata model as described in Section F-4 of this annex. The computed (model-based) isolation is the sum of the path loss between the point-to-point receiver and the PCS transmitters, building height gain and penetration loss if applicable, and reduction in the point-to-point receive antenna's maximum (on-boresight) gain if the PCS transmitters are off-boresight (antenna discrimination). The minimum value of isolation measured by the active avoidance system at multiple locations within the coverage area of the PCS base station or cluster should be the one employed in interference calculations to ensure the worst-case (highest received PCS power) situation is considered.

Example: An outdoor PCS cell is located in an urban area 10 kilometers from a point-to-point receiver, and is off-boresight from the point-to-point receive antenna by an angle of 50 degrees. The radiation pattern envelope of the point-to-point receive antenna at an off-boresight angle of 50 degrees is 32 dB down from the maximum (on-boresight) gain. The point-to-point transmitter co-located with the receiver has an EIRP of 65 dBm. Due to frequency division duplex operation of the PCS, the transmit power of only the PCS base station falls within the IF bandwidth of the point-to-point receiver, which has a center frequency of 1905 MHz (f). The PCS base station transmitter antenna is at a height of 30 meters (h_{Base}) and the point-to-point receive antenna is at a height of 150 meters (h_{MW}). An active avoidance system located within the PCS cell measures a maximum signal strength of -100 dBm (measured at the antenna, assuming 0 dBi avoidance system antenna gain) from the point-to-point transmitter co-located with the point-to-point receiver. Can active avoidance be used to determine if an interference situation occurs between the point-to-point receiver and the PCS base station at this location?

Solution: With the geographic separation technique, the path loss between the PCS base station and the point-to-point receiver is determined by employing the Hata large city urban model with the suburban correction factor (see Sections F-4.4 of this annex):

$$
\begin{aligned}
L_{pcs} &= 69.55 + 26.16\log(f) - 13.82\log(h_{mw}) \\
&\quad + \left[44.9 - 6.55\log(h_{mw})\right]\log(d) - \alpha(h_{Base}) \\
&\quad - 2\left[\log\left(\frac{f}{28}\right)\right]^2 - 5.4
\end{aligned}
\qquad \text{(F-5-1)}
$$

where

$$
\alpha(h_{Base}) = 3.2\left[\log(11.75\,h_{Base})\right]^2 - 4.97 \qquad \text{(F-5-2)}
$$

Solving this equation for the path loss between the PCS base station and the point-to-point receiver yields Lpcs = 128 dB. The calculated isolation is then

$$
\textit{Calculated Isolation} = L_{pcs} + \textit{Antenna Discrimination of Point-to-Point Antenna} \qquad \text{(F-5-3)}
$$

or 128 dB + 32 dB = 160 dB, using the geographic separation methodology. The isolation measured by the active avoidance system is

$$
\begin{aligned}
\textit{Measured Isolation} &= EIRP_{FM} - \textit{Received Signal Level} \\
&\quad + \textit{Receive Antenna Gain of Active Avoidance System}
\end{aligned}
\qquad \text{(F-5-4)}
$$

or 65 dBm - (-100 dBm) + 0 dBi = 165 dB. Since the measured isolation is greater than the calculated isolation, active avoidance may be used instead of geographic separation in this case to determine whether a PCS system can transmit at this location.

F-5.2 Aggregation

Active avoidance systems must take into account simultaneous exposure to point-to-point receivers from multiple PCS transmitters, including cases where transmitters controlled by multiple PCS licensees may potentially cause interference to a single point-to-point receiver. The power aggregation methodology described in Section F-3 of this annex shall be used with active avoidance systems.[31]

F-5.3 Coordination

Coordination of active avoidance PCS systems shall be conducted using the same distances required by Section F-3.2 of this annex for geographic exclusion systems. PCS applicants using active avoidance methodologies shall coordinate with potentially affected point-to-point users according to the procedure

[31] The potential number of PCS units producing interference could be dynamically controlled by the PCS system which could calculate interference potential and limit activity on a channel once projected interference reaches a certain level.

described in Section F-6 and Annex G.[32]

F-5.4 Fail-Safe Operation

Active avoidance systems shall be designed with a mechanism to verify the sensitivity level required to achieve adequate isolation, as defined in Section F-5.1. Active avoidance systems that dynamically control the number of simultaneous PCS transmissions shall enable a "fail-safe" mechanism if deterioration or failure of the point-to-point microwave or beacon signal detection capability occurs. This "fail-safe" mechanism shall instantaneously prevent further PCS transmissions until detection capability is restored. Active avoidance systems used as an alternative to model-based analysis, such as to set PCS system capacity during PCS system (re-)engineering, do not require the same "fail-safe" operation. For these systems, the detection capability shall be periodically verified, or calibrated, through appropriately conducted laboratory or field tests.

F-5.5 Out-of-Area Operation

All interference avoidance approaches, whether active or passive, shall employ a methodology that allows transmissions from mobile units only after the unit has actively received avoidance information. In the event that an active avoidance system is required but not operational, avoidance information would not be provided and therefore transmissions by PCS mobiles shall be precluded. Transmission by PCS mobiles shall also be precluded in those areas where either no base station coverage is provided or where avoidance information is not obtained or available.

F-5.6 One-Way Links

Active avoidance systems not employing beacon transmitters cannot measure RF isolation between receive-only point-to-point sites and PCS transmitters (see Section F-5.1 above). In those cases, the geographic separation methodologies described in Sections F-3 and F-4 of this annex shall be used exclusively for coordination between PCS systems and receive-only point-to-point sites. The geographic separation algorithm may be included in the active avoidance system and used as required.

F-5.7 Equipment Authorization

It is expected that PCS equipment will require authorization by the FCC prior to being marketed. Equipment designed to operate as part of or in conjunction with an active avoidance system may also require authorization by the FCC.

F-5.8 Operational Considerations

Active avoidance systems shall be capable of operating effectively in the presence of transmissions from nearby co-channel and off-channel PCS and point-to-point microwave transmitters. Since an active avoidance system is intended to accurately determine the value of isolation to a particular point-to-point microwave receiver or transmitter, the system shall exhibit immunity to overload effects or intermodulation distortion that may result due to nearby PCS and/or point-to-point microwave transmitters. For receive-only

32 The argument could be made that active avoidance systems do not require coordination and, instead, can be put into service without completing this process. However, the basic premise of shared spectrum involves the review and agreement by other potentially affected parties that interference will indeed be improbable.

systems, the sensitivity of the active avoidance system shall be specified considering the required level of isolation between PCS and point-to-point microwave systems. Active avoidance systems must have the capability to account for multiple fixed microwave receivers.

F-6 Prior Coordination Notices

Upon completion of the interference analysis process, the PCS applicant shall notify all existing users and applicants with previously filed applications within the applicable coordination distance, allowing them adequate time (30 days) to respond regarding their concerns. Refer to Annex G for details on prior coordination procedures.